

► Remote Field Eddy Current Inspection of Unpiggable Pipelines

Natural Gas Delivery Reliability Kickoff Meeting

National Energy Technology Laboratory
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Unpiggable Pipeline and LCD Transmission Mains Typical Obstacles

- **short radius bends; cutoffs; branching to services**
- **in many cases, flow rates inadequate to support smart pig propulsion**
- **reduced port valves**
- **few launching and receiving ports**

Requirements for Pipe Integrity Tools for Unpiggable Pipelines and Distribution Mains

- **Safe Assessment of Condition**
 - No Interruption of Customer Service
 - Maintain Sufficient Flow Rate
 - Minimize modifications needed to line
- **Information on Wall thinning, External or Internal Damage, Cracks, Dents, etc.**
- **Acceptable Economics & Operating Practices**
 - Minimize Excavations
 - Net Added Value over Cost

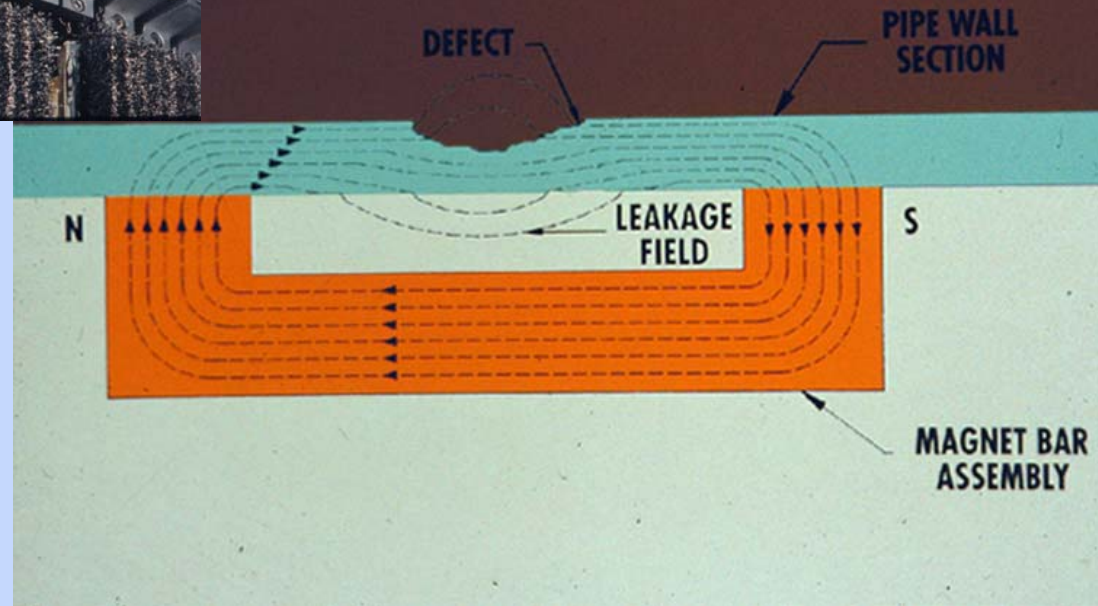
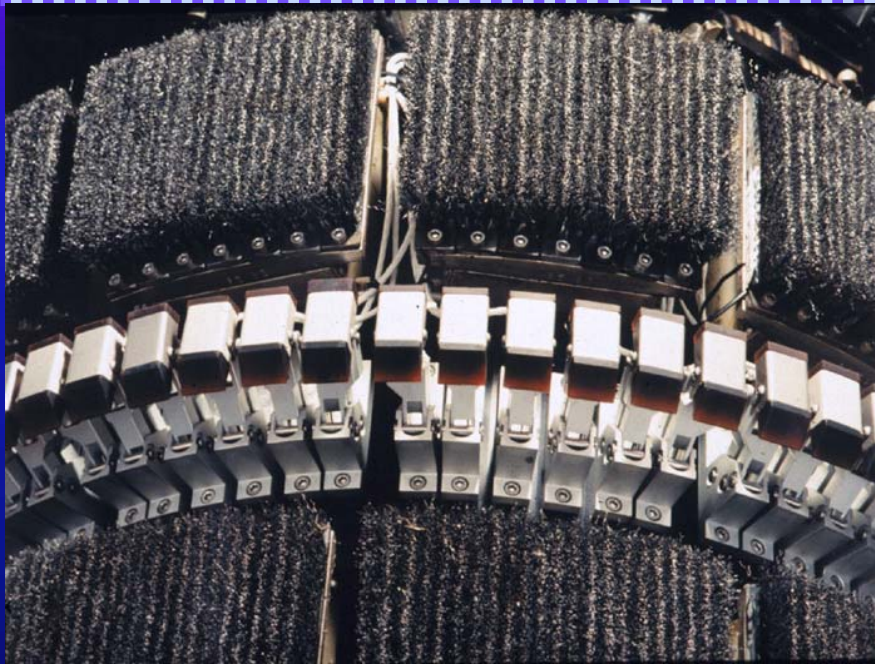
Requirements for Ultimate Inspection Technology

- **Applicable for pipe sizes ranging from 4" - 36" ; may require multiple approaches for different sizes**
- **Ability to operate in live gas conditions**
- **Consistent performance for all soil types and ground cover conditions**
- **Ability to manage the challenging characteristics of LDC-owned transmission mains and transmission pipelines with minimal excavations**

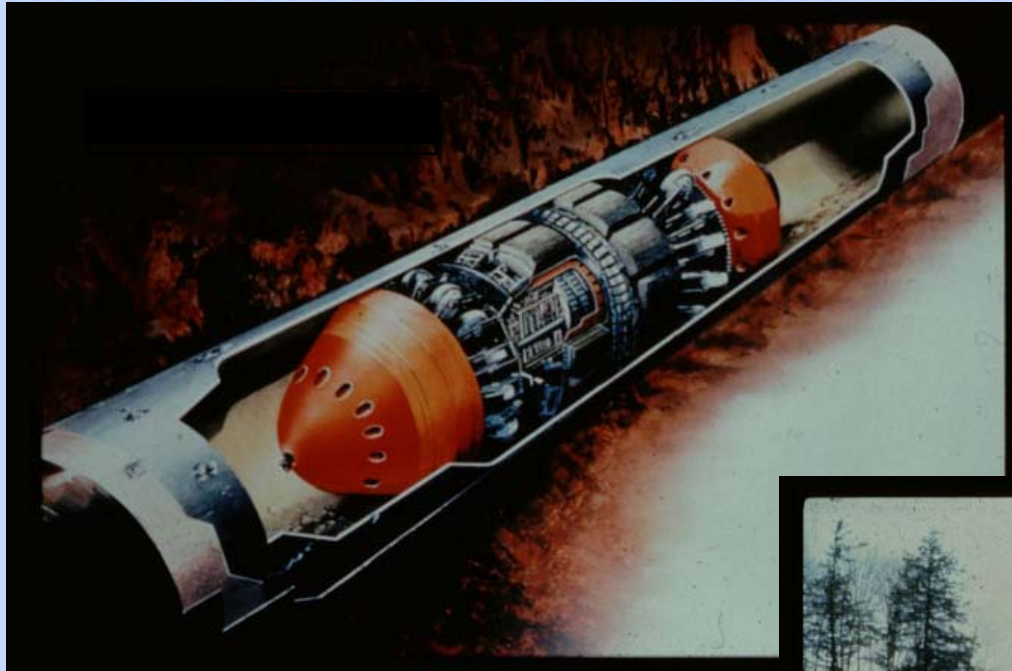
Challenges for Unpiggable Pipelines

- **Self-powered and capable of traveling long distances**
- **Passable through plug valves**
- **Automatically adaptable, by a factor of two, to changes in pipe diameter**
- **Navigable in both horizontal & vertical planes**
- **Negotiate mitered elbows, tees and back-back bends**
- **Occupy less than 50% of the pipe area**

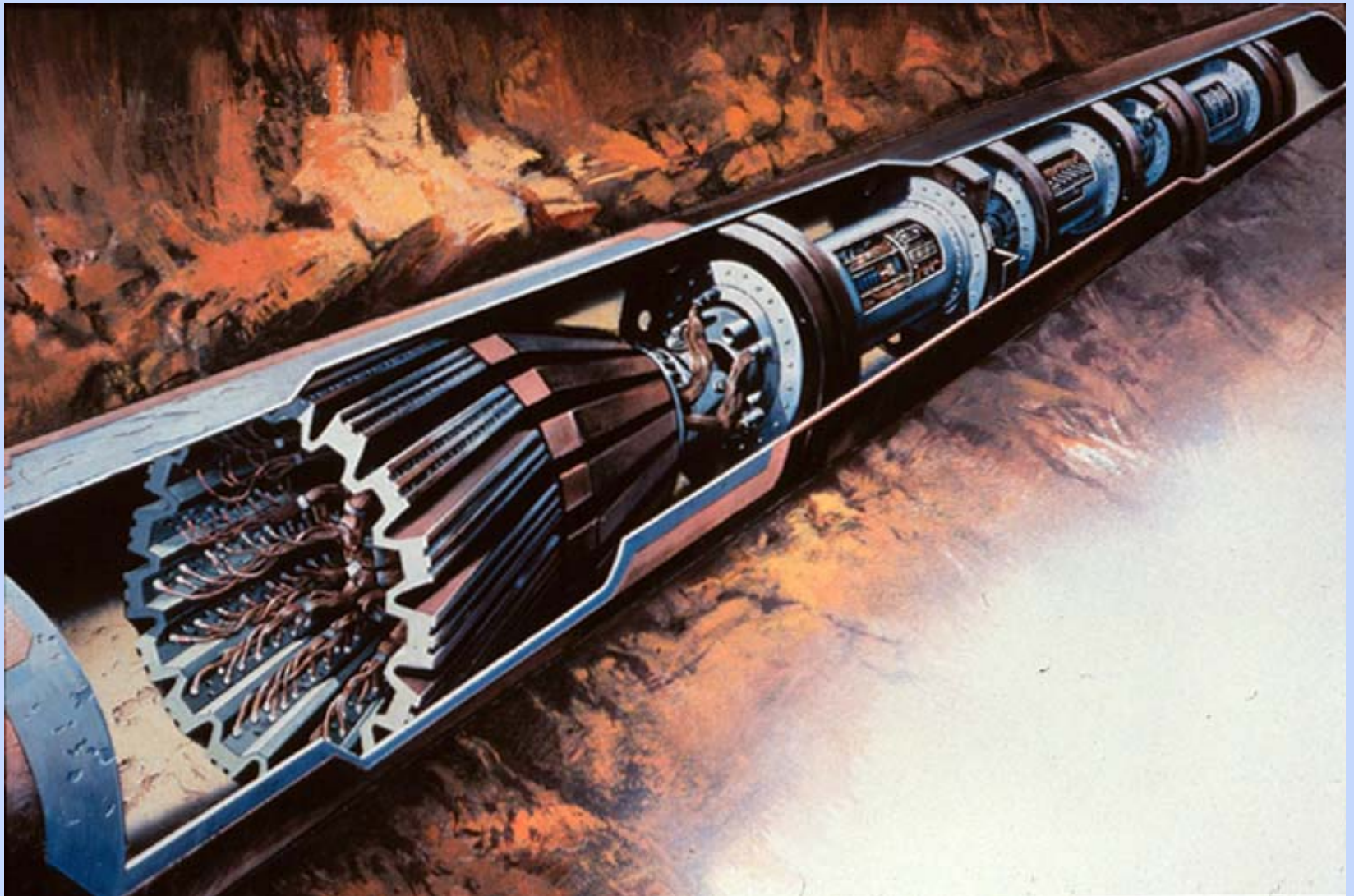
Magnetic Flux Leakage Inspection



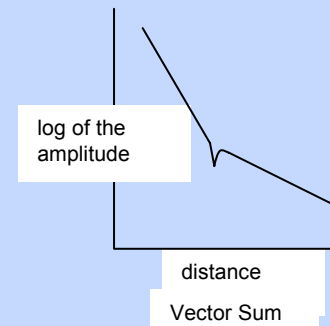
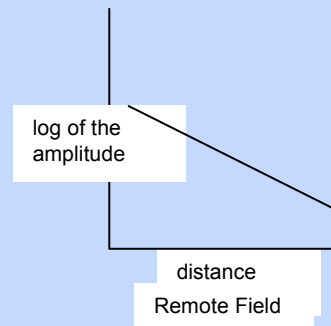
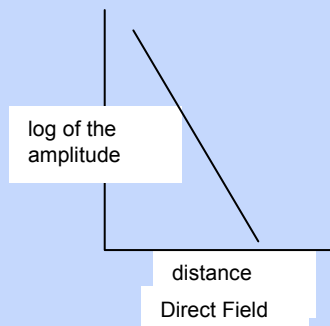
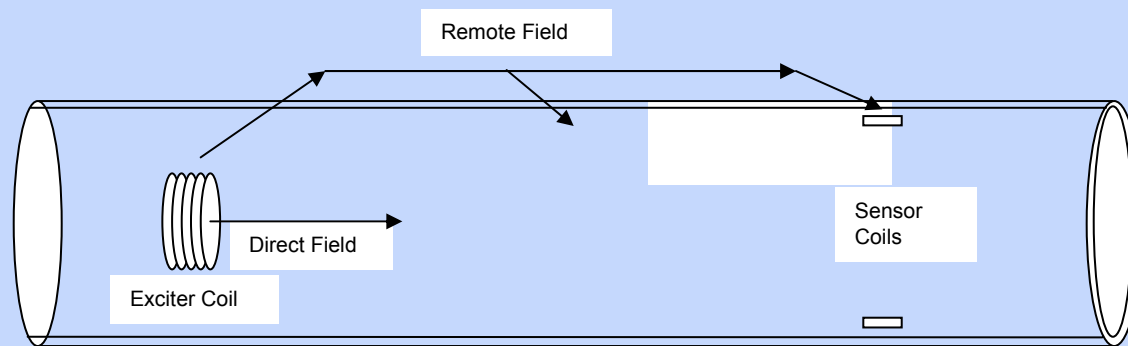
Magnetic Flux Leakage Inspection



Ultrasonic Inspection



Remote Field Eddy Currents (RFEC)



RFEC Inspection Vehicle

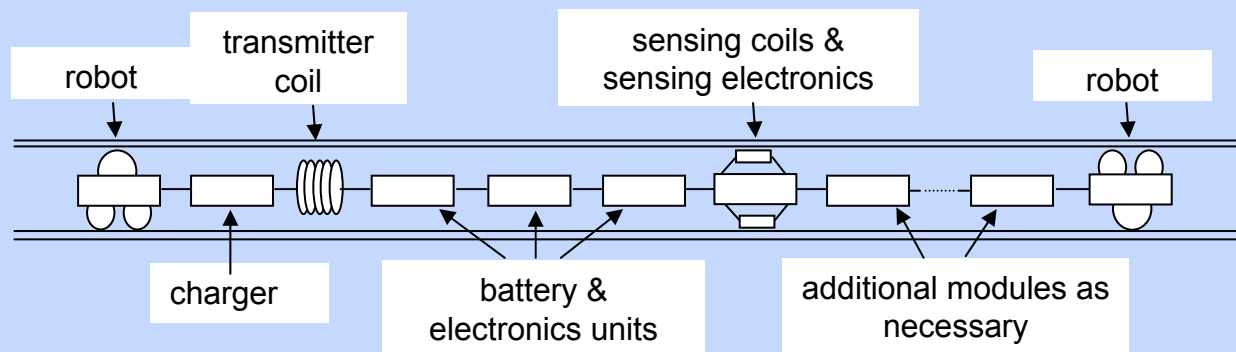


Figure 2. RFEC Inspection Vehicle

RFEC Inspection Vehicle Electronics

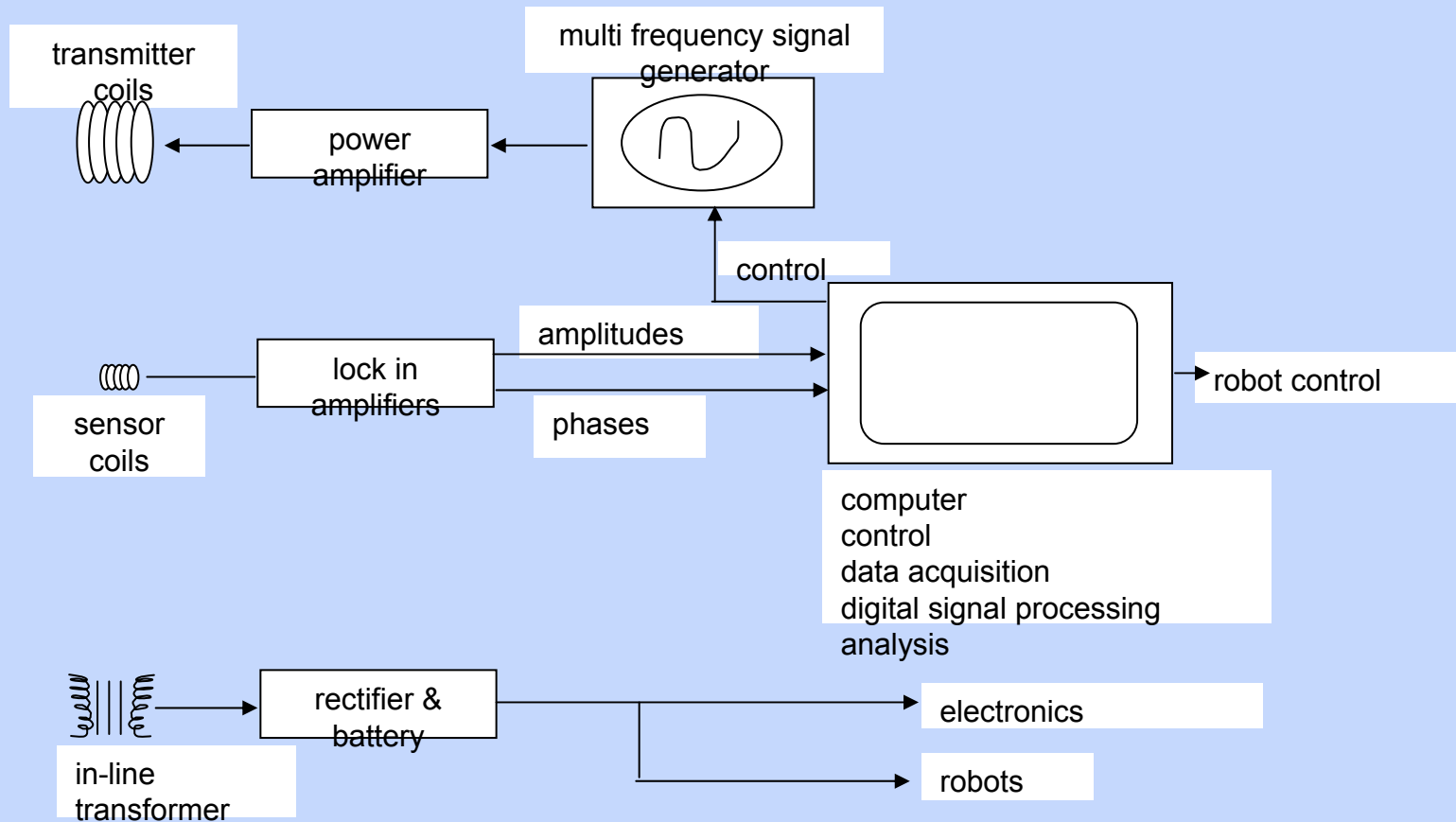
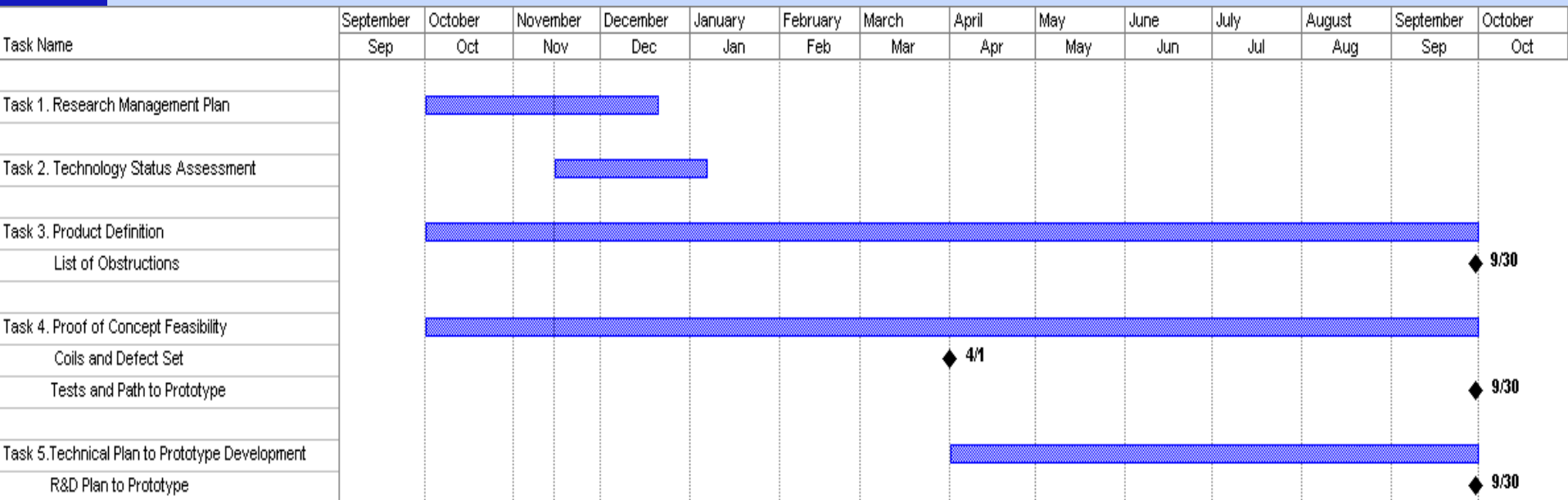


Figure 3. Electronics and power supply

RFEC for Unpiggable Pipelines

- **Work started 1 October 2002**
- **Research Management Plan submitted**
- **Technology Assessment Report submitted**
- **Coil winding has begun**

Research Management Plan



Research Management Plan

- **Task 1: Research Management Plan**
- **Task 2: Technology Status Assessment**
- **Task 3: Program Definition Obtain detailed information from transmission and distribution companies about unpiggable pipelines and their operations**
 - ○ Obtain information about distribution companies with gas mains
 - ○ Obtain information about gas transmission companies
 - ○ Obtain information about companies with both transmission and distribution capabilities
 - ○ Prepare a list of obstructions and operating conditions that make a pipeline unpiggable.

Research Management Plan

- **Task 4: Proof of Concept and Feasibility _ Adapt existing RFEC technology to inspect unpiggable pipelines**
 - ○ **Optimize transmitter coil configuration**
 - ○ **Optimize sensor coil configuration**
 - ○ **Optimize the frequencies**
 - ○ **Build a prototype laboratory tool**
 - ○ **Test the prototype in a six inch pipe in the laboratory**
 - ○ **Compare the performance to the performance of an equivalent Magnetic Flux Leakage (MFL) inspection tool.**
- **Task 5: Technical Plan to Prototype Development _ Develop a detailed R&D plan for prototype development**
 - ○ **Inspection tool design**
 - ○ **Electronic specifications**
 - ○ **Mechanical specifications**
 - ○ **Test pipe configurations**

Technical Assessment

- **David Atherton of Queen's is a world expert on RFEC and owns a rapidly growing company that uses the technique to inspect large diameter water lines**
- **Russell Technologies is a leading manufacturer of RFEC probes and David Russell is pioneer and leader in the industry**

Technical Assessment

- W. R. McLean, US Patent 2,573,799, “Apparatus for Magnetically Measuring Thickness of Ferrous Pipe”, Nov.6, 1951
- Schmidt, T. R., “The Casing Instrument Tool- ...”, Corrosion, pp 81-85, July 1961
- Atherton, D. L., US patent 6,127,823, “Electromagnetic Method for Non-Destructive Testing of Prestressed Concrete Pipes for Broken Prestressed Wires”, Oct. 3, 2000
- Schmidt, T.R., Atherton, D.L., and Sullivan, S., “Experience with the Remote Field Eddy Current Technique”, Pro. 3rd Nat. Sem. on Nondestructive Evaluation of Ferromagnetic Materials, Houston, March 23-25th, 1988
- www.physics.queensu.ca/~amg/papers/rfec_papers.html

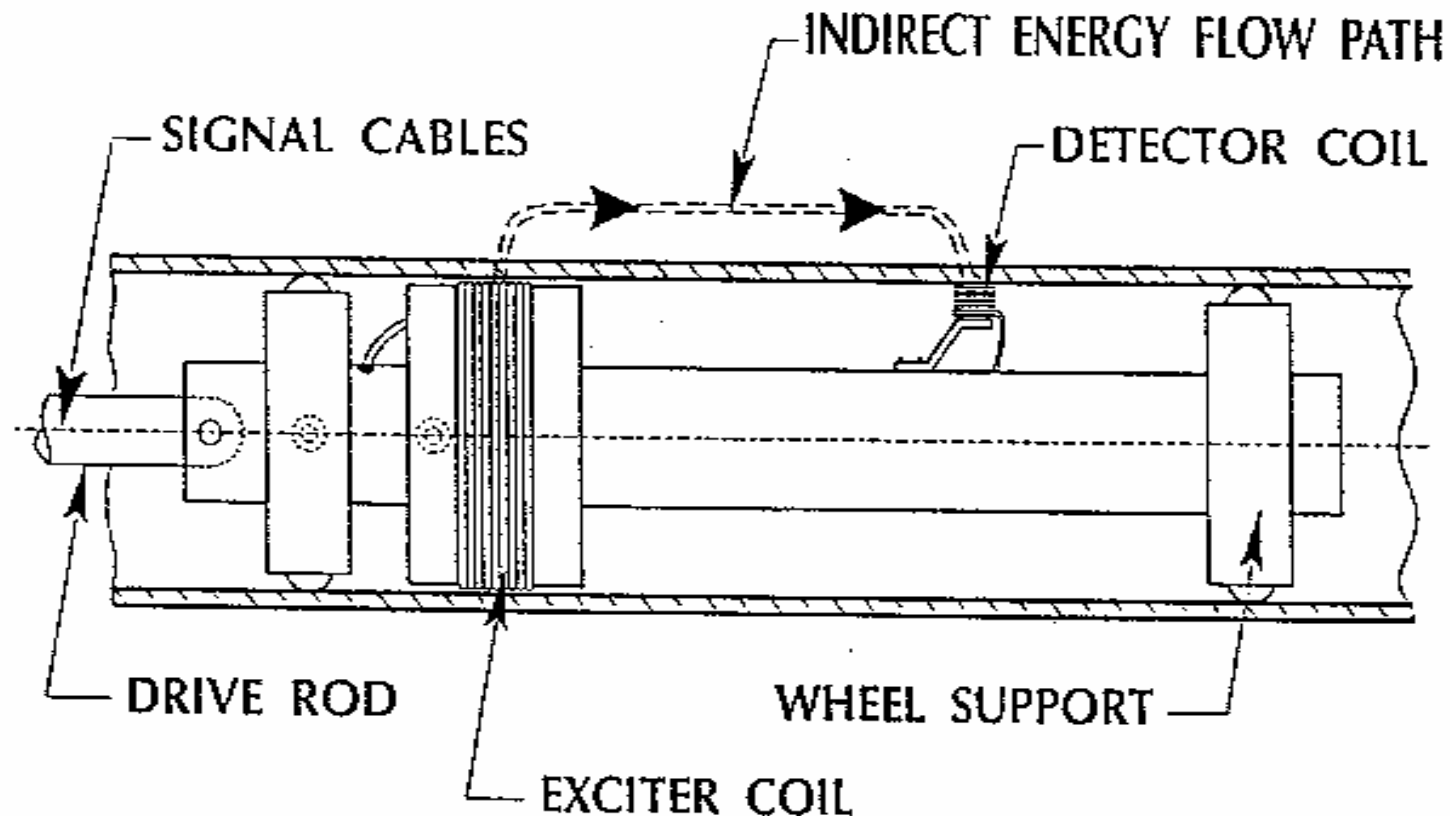
Benefits to Gas Consumers and Gas Industry

- **Inspection of “unpiggable” pipelines enhancing safety**
- **More reliable inspection**
- **Quantitative measurement of “unpiggable” pipeline flaws**
- **Reduced pipeline reliability and safety assurance costs**



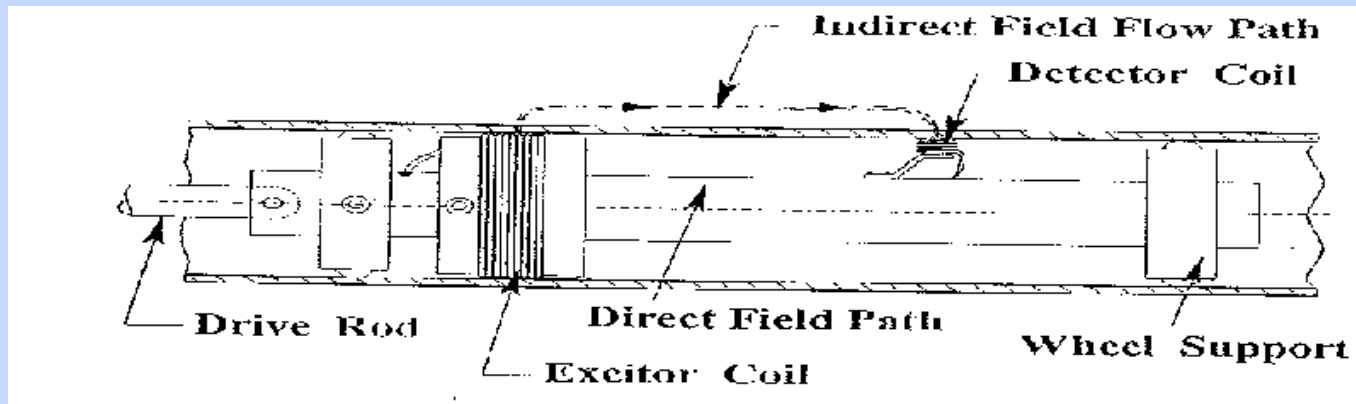
Creating Technology Solutions with Impact
Across the Energy Spectrum

The Remote Field Eddy Current Probe

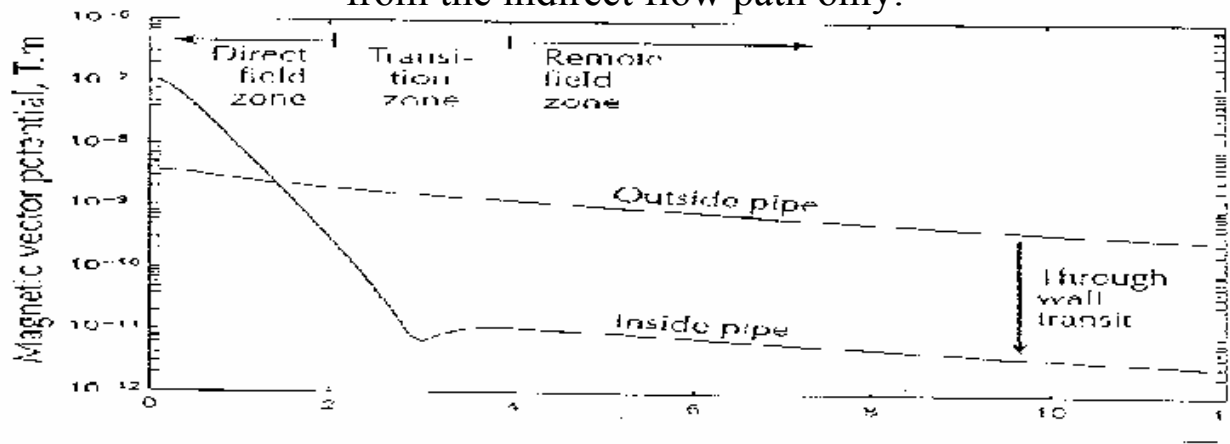


Simplified schematic of an RFEC probe in a pipe showing the indirect flow path. The detector or array of detector coils, which may be oriented to sense either the axial or radial field components, is displaced axially from the exciter by typically 1.5 to 2 pipe diameters.

Typical Response of a RFEC probe

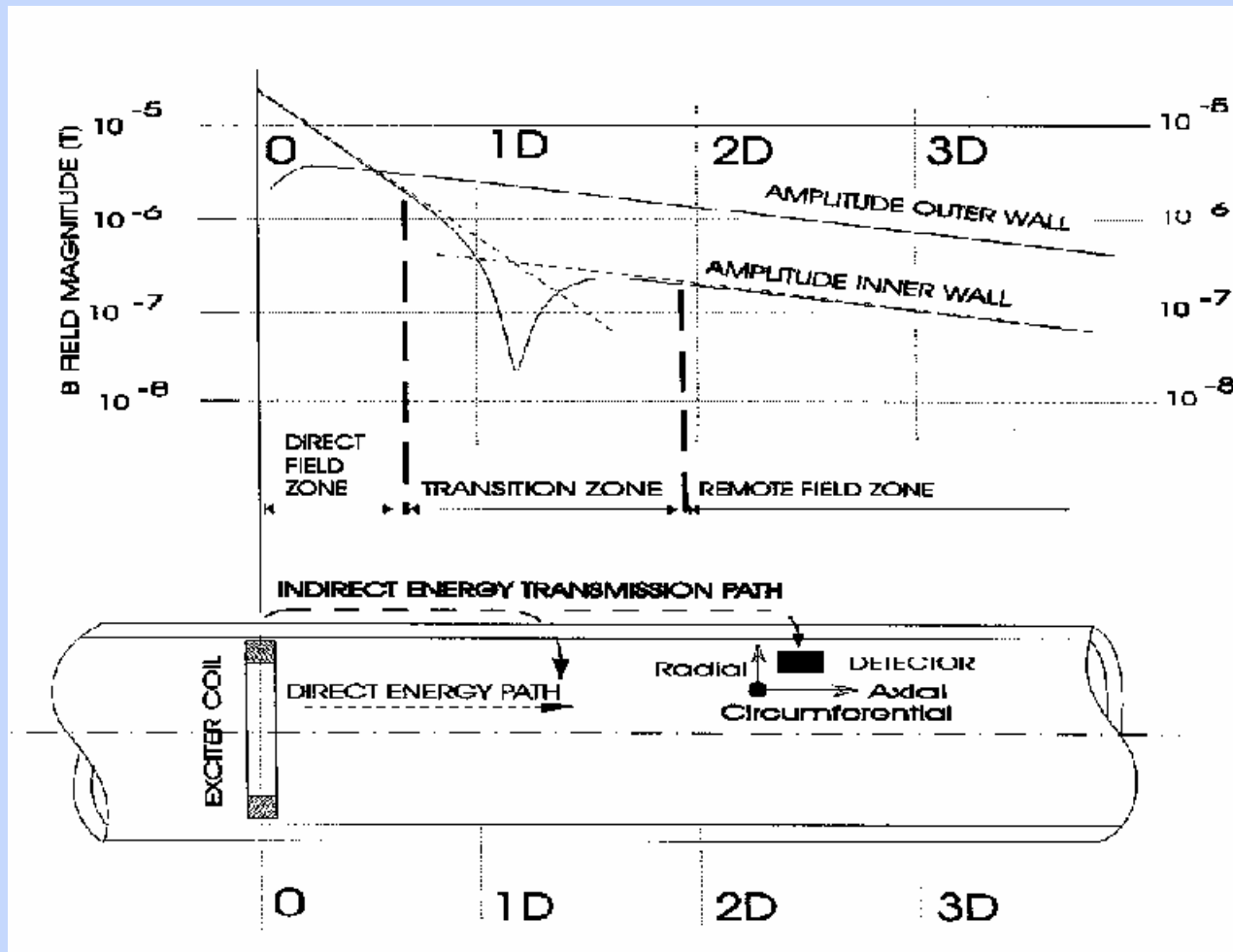


A simplified RFEC probe. In the remote field zone, the detector receives energy from the indirect flow path only.



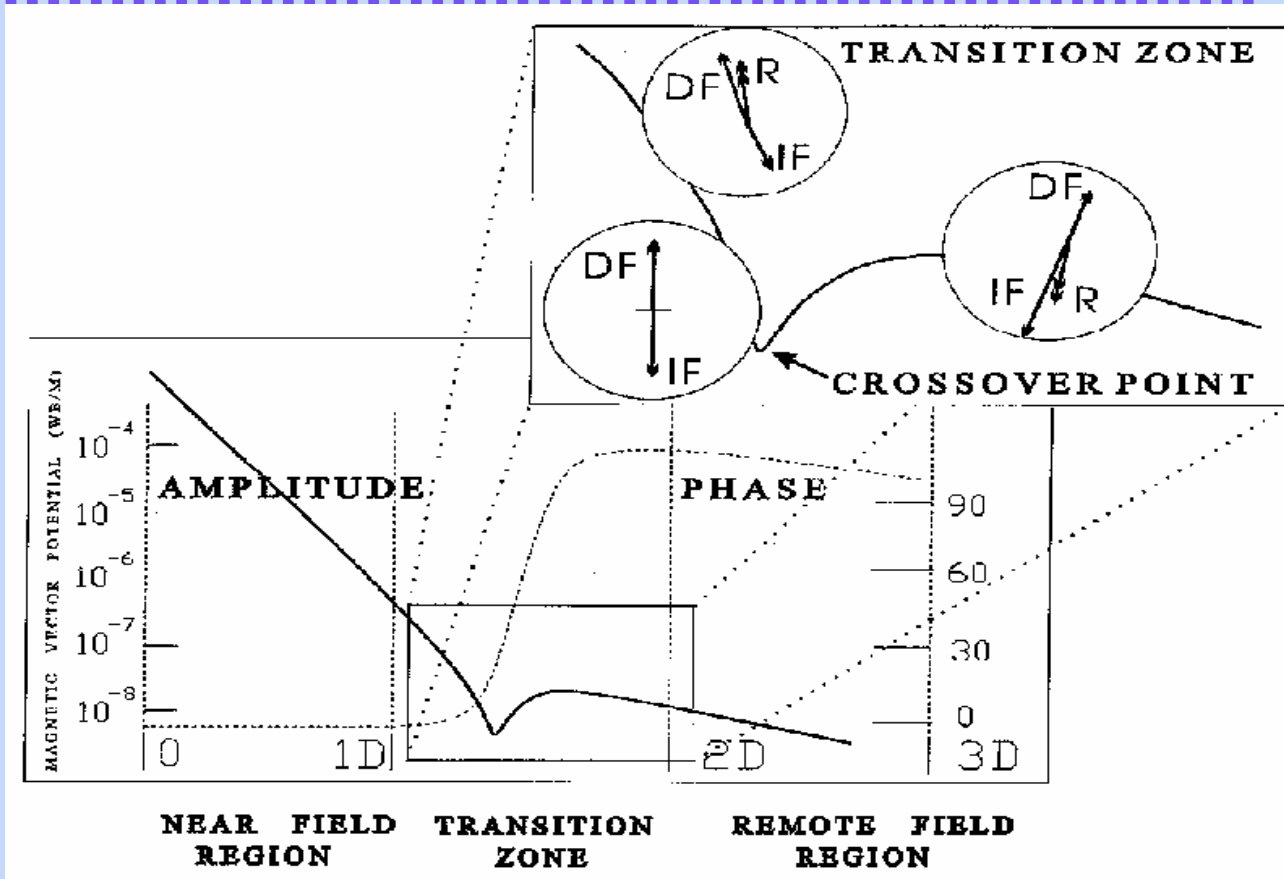
A typical response seen by a Remote Field Eddy Current probe. The topmost curve is the observed signal along the outside of the pipe. The bottom curve is the observed signal along the inside of the pipe.

The Remote Field Zone

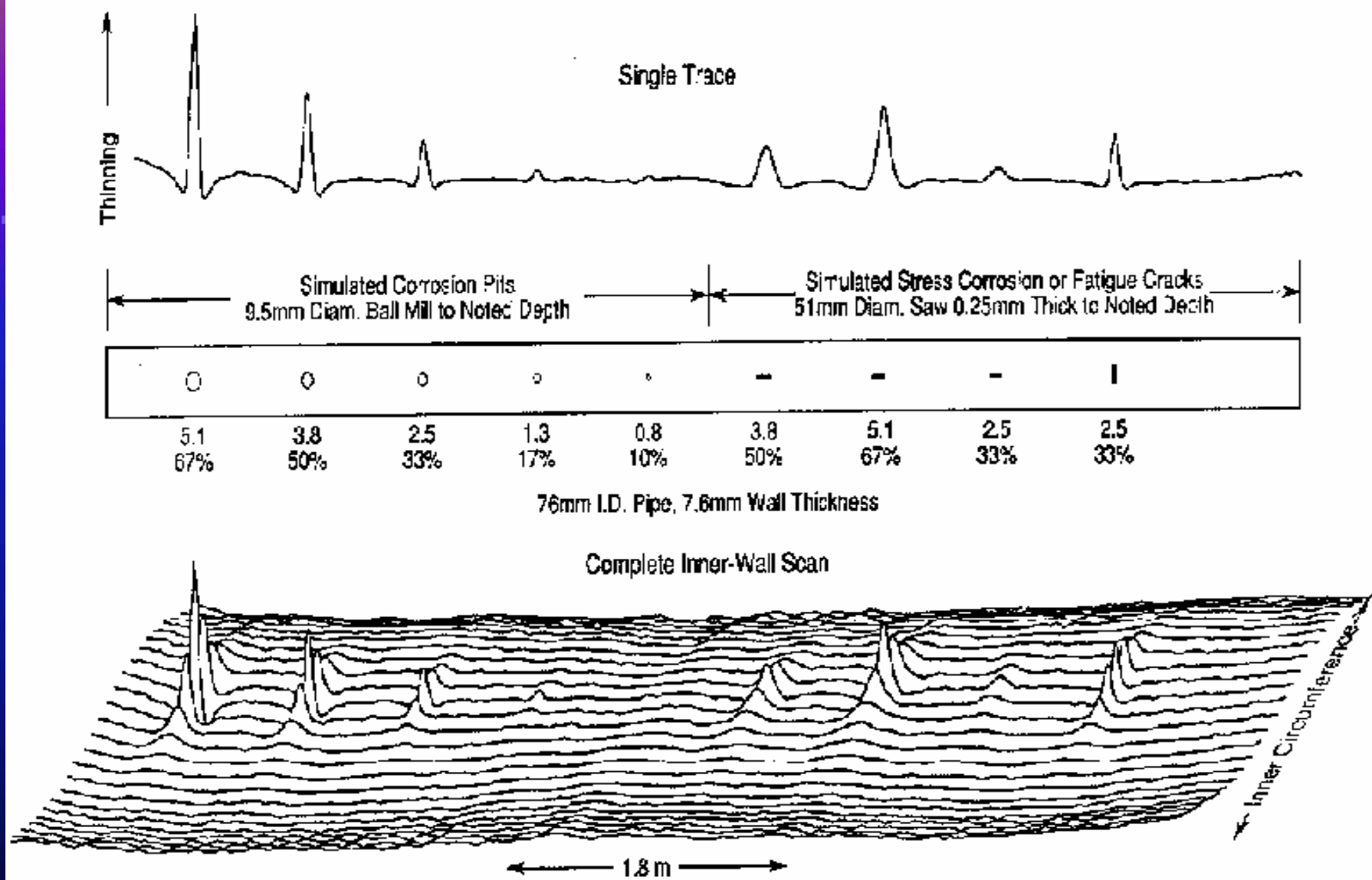


Schematic of an RFEC probe in a pipe showing the direct and indirect energy flow paths and profiles of the B field magnitudes just inside and outside the pipe. These are used to indicate the direct-coupled field region, transition and remote-field zones.

More on the Transition Zone

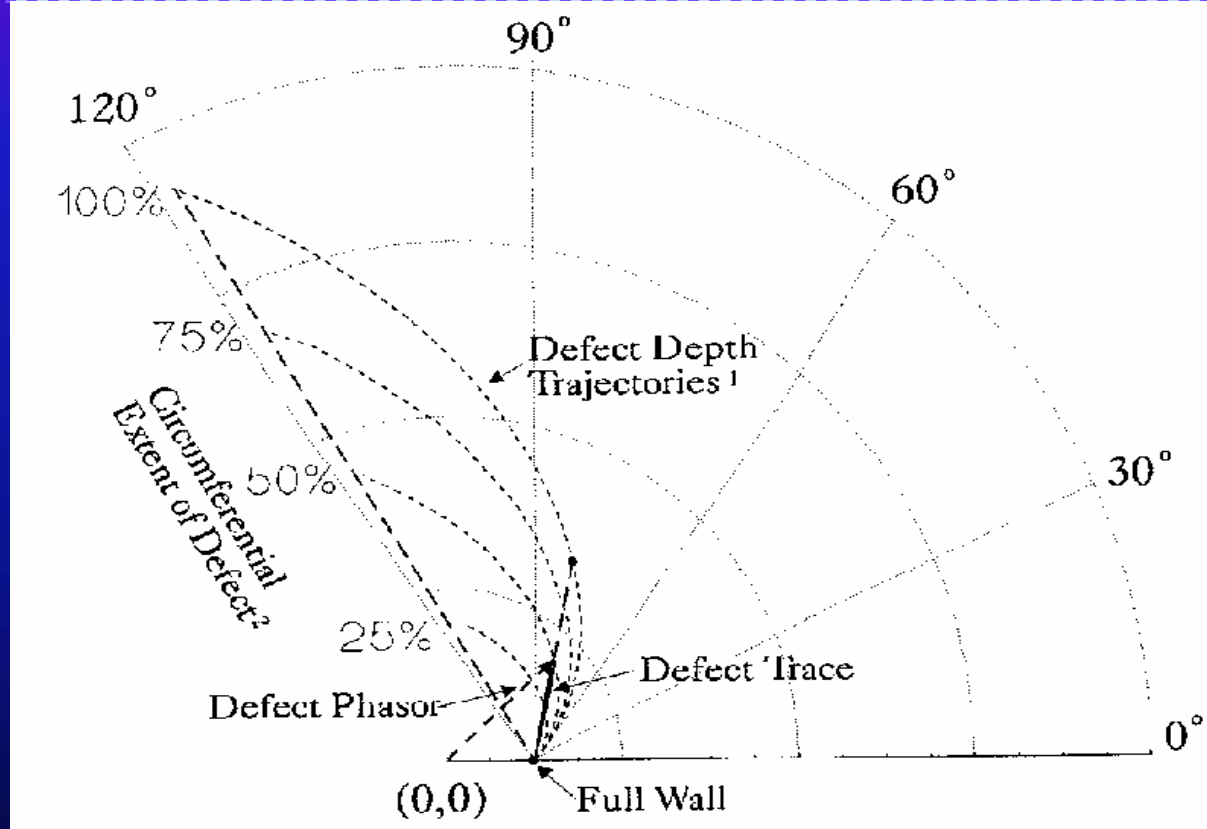


The variation of RFEC amplitude and phase of the field measured along the inside wall of a pipe showing an enlarged view of the transition zone. Insets depict the interactions between the direct field, DF and the indirect field, IF. These will combine to produce a very small resultant field, R, at the crossover point, where the direct and the indirect fields are of equal magnitudes, if they are also in antiphase there.



The classic illustration from T.R. Schmidt, "The remote field eddy current inspection technique", *Materials Evaluation*, vol 42, pp. 225-230, 1984, showing RFEC indications of external simulated flaws in a steel pipe, as sensed by field phase logs made around the full inner circumference.

RFEC Monitor Display



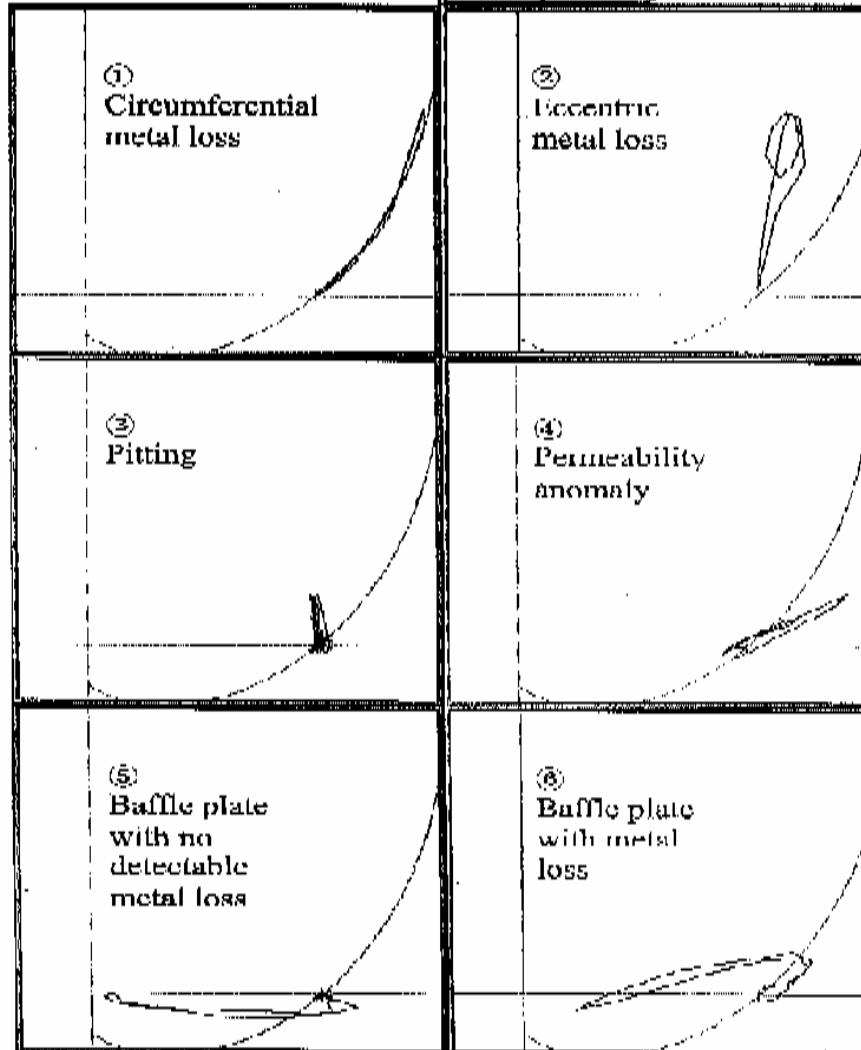
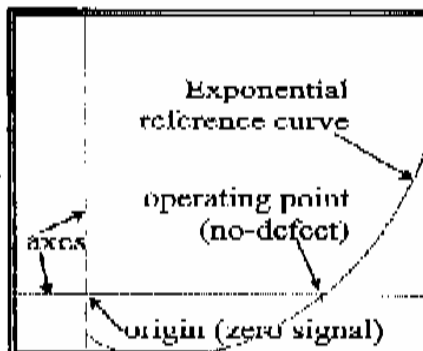
1. Spiral of constant circumferential extent, amplitude increasing with defect depth.

2. Line of constant defect depth, amplitude increasing with circumferential extent of defect.

The standard RFEC voltage plane polar plot (VPPP) showing defect depth trajectories and circumferential extent lines derived using skin depth approximations for solenoidal detectors.

These are used to analyse the defect trace. The detector signal is normalized and rotated so that the full wall signal in defect-free pipe is shown at the (1,0) position. Wall thinning causes decreases in attenuation and phase lag and therefore gives an exponential spiral response normalized to the circumferential extent of the wall thinning.

Voltage plane
with reference
markings
(no data)



Typical RFEC voltage plane
polar plot
defect signatures. Metal loss
defects are identified by the
position of the signal trace
relative to the exponential skin
depth reference curve. Numbers
on defects correspond to those
on the previous graphic.